An Approach for Intuitive Visualization of Ergonomic Issues

Walentin Heft[1(✉)], Michael Spitzhirn[2], Angelika C. Bullinger[2], and Paul Rosenthal[1]

[1] Visual Computing Laboratory, Department of Computer Science, Technische Universität Chemnitz, Chemnitz, Germany
{walentin.heft,paul.rosenthal}@informatik.tu-chemnitz.de
[2] Ergonomics and Innovation Management, Department of Mechanical Engineering, Technische Universität Chemnitz, Chemnitz, Germany
{michael.spitzhirn,angelika.bullinger-hoffmann}@mb.tu-chemnitz.de

Abstract. Ergonomics is the science of human work. One goal is the adaption of work to the human, thus to create better working conditions and to avoid health risks. Increasingly often, digital human models and corresponding evaluation methods are used. Due to the mass of data and the variety of possible analyses which come along with a simulation, the interpretation of the outcomes can take a long time. We introduce a new concept, which enables a quick and understandable visualization and navigation of critical ergonomic situations and their causes. There are filter mechanisms available for changing the level of detail. These enable a representation for specific target groups. Prior to the development of the concept, expert interviews were conducted to specify the user requirements. Each iteration step of the design process was evaluated in cooperation with ergonomics experts.

Keywords: Overview and glyph-based visualization · Ergonomics · Concept study

1 Introduction

An important property of visualization is its interactive nature. It is necessary to consider some simulation results, analyze them, and change parameters for a better understanding. Typically, a reconsideration from another viewpoint or comparison of the several outcomes has to be conducted. Furthermore, user interaction is often needed because of the mass of data which is not perceptibly at a glance. Especially in research and industry, experts use visual analytics tools to detect ergonomic problems [1]. Modest circumstances concerning ergonomics could increase working time and costs. During the beginning of professional ergonomics, ergonomists used life-size human models and prototypes, for example, to design vehicle interior. These days they are using computers and ergonomics software tools, such as digital human models (DHM), to visualize results for a fast processing and understanding. While some ergonomists

V.G. Duffy (Ed.): DHM 2015, Part II, LNCS 9185, pp. 26–36, 2015.
DOI: 10.1007/978-3-319-21070-4_3

still use tables in hard copy for their analysis, the following surveys show the importance of ergonomics software tools in all areas of product planning, manufacture, and usage. The results of a survey carried out by Wischniewski [2] indicate that for the majority of the sample, ergonomics tools are important today. Most of the 30 domain experts, which participated in the survey, think that these tools will take an inherent part of virtual ergonomics evaluation in the future. Another survey carried out by Muehlstedt [1] with 59 experts also emphasizes the importance of ergonomics tools. Especially the analysis function in the matter of visualization (as picture or video) next to measurement, and posture were considered to be relevant.

2 Potential Users and Requirements

In order to create an interactive visualization of ergonomics information, we had to determine potential users and their requirements. Often several target groups work on the same data base, but with different intension and from different angles. For this purpose we interviewed professionals in the field of ergonomics, the occupational health and safety department (HSE), and industrial engineering (IE) from Deutsche Bahn AG (German Railways). Six experts participated in this workshop. A further workshop was held at the Volkswagen AG with two experts. We identified the main groups of potential users and their requirements in moderated interviews. All things considered, we obtain three main areas. In the first area experts are responsible for planning and designing of work processes. This includes professionals of HSE, IE, as well as planers and designers. The latter define the final product design in collaboration with ergonomists, HSE, and the IE. They are also responsible for the implementation of the working system. The industrial engineers set, among other things, time standards. A further group of potential users are persons who actually produce the goods. Here, workers are responsible for the correct execution of the working task and they are assisted by the team leader. The team leader takes the responsibility for decision-making, monitoring, and advisory to maintain the quality and quantity goals in the production. The person has also to decide about the deployment. Hereby, the work requirements and individual productivities of the corresponding employee have to be matched [3–5]. The last area consists of the work council and management. The former is the representative of workers' interests. The management deals with economic aspects. This also includes the investment costs of workplace design.

In the following, the mentioned requirements of the participants of the workshops are explained in more detail. The respondents expressed their desire for an easier handling. In general, existing ergonomics tools are too complicated, as they told us. There is a high learning curve and a new incorporation is necessary after a few months without using the corresponding software, in particular in DHMs. In order to counter these problems, explanations, such as mouse-over info boxes on all interactive elements are wanted. The second wish was a user-friendly representation of the analysis data. The design should have an eye-catching character. In their experience, most non-ergonomists aren't interested

in tables. Color coding is preferred over tables. Furthermore, as the ergonomists mentioned, intuitive and sustainable graphical user interfaces are requested to demonstrate the ergonomic-critical situation in workshops, which are held for the workers. Many workers do their work already for years in the same manner. They very often lack the understanding of the necessity of the advantages the workers obtain due to ergonomic analyses of their workplaces. In addition, a prioritization is required to set a focus on major problems, such as bending. A visualization of ergonomic data should also consider that the same data has to presented in different forms, depending on whether they talk in front of the management or the workers. In result, important ergonomic issues should be visible at a glance and additional information should be provided on demand in a simple way.

3 State of the Art

Although the variety of visual metaphors is quite broad, the used approaches seem very simplistic and in many cases not human centered enough to facilitate an optimal process by ergonomists. We have recently presented an overview about the state of the art in virtual ergonomics with regard to visualization issues [6]. There are several methods to conduct ergonomic analyzes of workplaces, e.g., posture or load. We want to briefly introduce two of them, RULA and EAWS. The ergonomic tool RULA ("Rapid Upper Limb Assessment") can be utilized to investigate "the exposure of workers to risk factors associated with work related upper limb disorders" [7]. It is a gross screening method which evaluates the body posture (upper arms, lower arms, wrists, neck, trunk, and legs), based on the body angles, the applied forces and loads, the proportion of static muscle work, and the number of repetitions. The result is a rating of the working conditions, which ranges from one (no risk) to seven (high risk). In addition, a separate evaluation of the single body segments can be done. The use of the method is easy to learn [8]. With the ergonomic system EAWS ("Ergonomic Assessment Worksheet"), the biomechanical risk factors for musculoskeletal disorders can be evaluated during a working shift. The evaluation process consists of different sections, such as an assessment of additional ergonomic loads (for example caused by working on moving objects) or an assessment of static or high repetitive postures. EAWS is more complex and the method requires significant more information for a judgment than the method RULA.

As mentioned before (see Sect. 1), ergonomic investigations in companies are surprisingly often carried out by measuring or capturing data using paper-pencil methods and simple software support. For ergonomic reports, standardized sheets, such as the EAWS scoring sheet or simple diagrams, are applied as visualization. In addition, ergonomic maps or exposure registers are used for the documentation of an ergonomic evaluation of several work stations. The visualization of this kind of work is typically done using simple floor plan sketches or plain (Excel-) tables. A workstations can also receive a color coding according to the common standard DIN EN 614 (green, yellow, red) or separate evaluation points for a sharper disjunction [9].

Digital human models are becoming more and more popular [10] and usage is growing [11]. The presentation of ergonomic results with software is often bounded to lists, simple dialogs, or simple graphs. An excerpt of the most common representations of ergonomic reports in digital human models can be found in Figs. 1 and 2. The introduced tools are not able to pass the above mentioned design requirements. There is no possibility to select the depth of analysis and only information about a static pose can be displayed, instead of an overall view. The current visualization in DHM does not support the user in analyz-

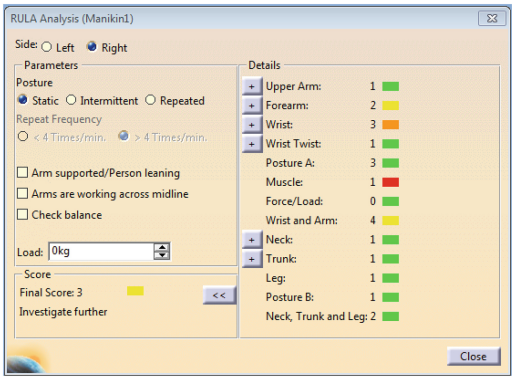

Fig. 1. Ergonomic report of RULA in the DHM "Human Builder". On the left-hand side, the ergonomists have the possibility to tune the analysis results for the corresponding body side, the final score, as well as further parameters. On the right-hand side, there are color coded fields for several body parts. The colors indicate the level of stress on the body joints (Color figure online).

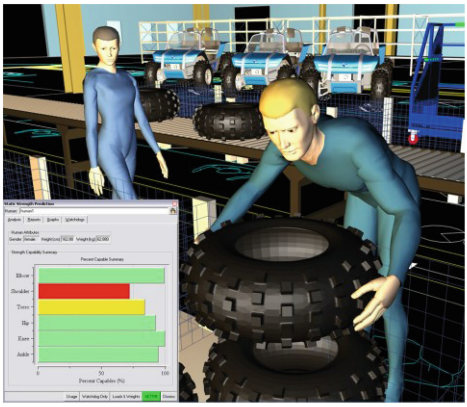

Fig. 2. Ergonomic report of RULA in the DHM "Jack" [12]. The report is displayed in a 3D scene. Here, a static pose of a male worker is considered. The analysis results are color coded for several body parts (e.g., the elbow or the shoulder), as shown in the bottom left corner.

ing ergonomic critical situations in an adequate way. The current presentation tends to demonstrate data in the absence of a context relation and without the possibility to change the depth and range of analyzing. Thus, there is room for improvement.

4 Related Work

Since time-oriented data is relevant in many practical situations, the visualization of such data has a long tradition [13] and still many recent work exists [14–16]. However, visualizations in digital human models for showing critical ergonomic situations or illustrating time-oriented processes are very limited. The concept of timelines is used in LifeLines [17]. LifeLines was developed to create an overview over certain events in the life of a person. Therefore, the authors make investigations in hospitals, to receive facts about deseases, visits to the doctor, and so on. The presence of all import information at one stage enables the doctors to make a better prognosis about the medical condition and to offer a more suitable therapy. However, an overview of a huge amount of data can still quickly lead to confusion. LifeFlow [18] delivers a possibility to counteract this circumstance with event sequences (series of temporal distinct and consecutive events). Matchpad [19] presents an interactive glyph-based visualization for realtime sport events. The events are directly visualized in an overview, during the match. SoundRiver [20] makes an audio-visual mapping to illustrate sound effects from audio sources, like movies (e.g., for hearing-impaired viewers). In this way, it symbolizes the noise of an airplane as an icon with a small aircraft, for example.

5 Evaluation Procedure

Based on the investigation of the user requirements (see Sect. 2), a first mockup was designed (see Fig. 3). We evaluated this concept with an informal survey and with the help of five ergonomic and usability experts that did not participate in the initial workshops. At the beginning of the survey, the participants were explained the aim and the single tasks of the respective parts of the mockup. After that, they had several minutes of time to internalize the visualization. Following, the interview was conducted. The experts were asked about the single components and the overall impression. On basis of the feedback and several further feedback loops, the new concept was designed in an iterative process.

6 Design Process

The initial (Fig. 3) and the final version (Fig. 4) follow Shneidermans seeking mantra “overview first, zoom and filter, then details-on-demand” [21]. Nevertheless, our user study led to significant changes, related to the initial design.

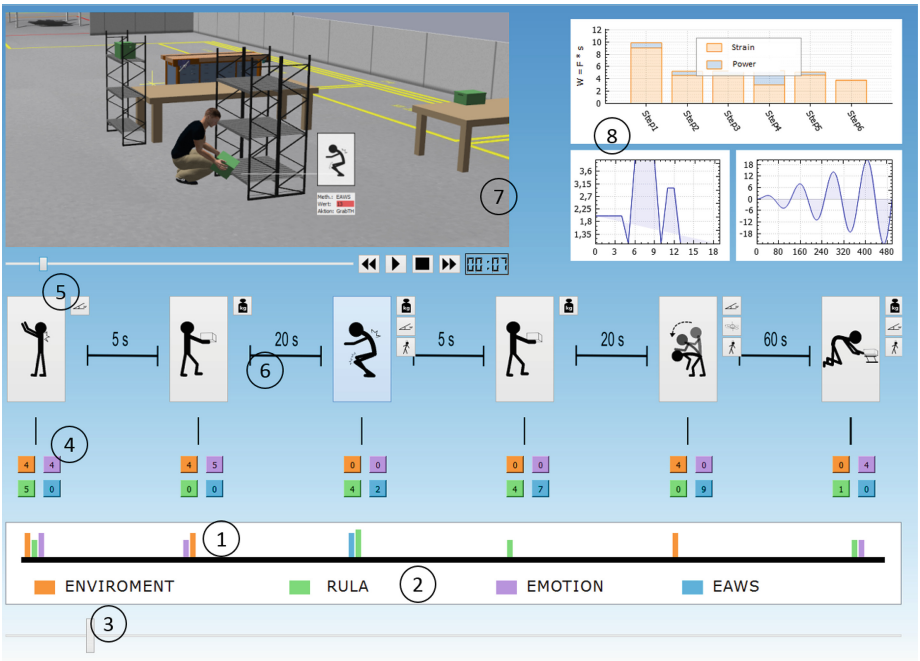

Fig. 3. Initial concept. (1) Timeline (2) Legend (3) Slider (4) Evaluation-scores (5) Pictogram with additional stress hints (6) Distance time between critical situations (7) Video sequence player (8) Further information about critical situations

The general concept shall contain a timeline for an overall view of all critical situations. We have deliberately avoided to display the overall workflow. First of all, ergonomic problem cases require a special investigation. In the initial version the design point (dp) 1 of Fig. 3 shows the timeline with vertical colored bars. The bars are located at the time, where the corresponding critical issues occurred. The colors refer to the legend beneath the timeline (Fig. 3: dp 2) and indicate the method, which delivers a poor score for an ergonomic event. The height of a bar depicts the severity of the problem. We use a slider (Fig. 3: dp 3) to specify the moment where to start with the analysis. From that point on, the following six critical ergonomic situations are displayed in more detail. The related results (Fig. 3: dp 4) are shown at a glance. Every value, in the colored boxes, represents the analysis result of the corresponding evaluation method. These colors also relate to the legend (Fig. 3: dp 2), as previously mentioned. In addition to the analysis scores, further information is necessary, such as the adverse posture of the worker as pictogram (Fig. 3: dp 5), which leads to a bad score, or hints to other reasons for this (see Fig. 3: dp 5, upper right corner). The "stickman"-pictograms are based on the depiction of poses from EAWS. An advantage is the high recognition value for ergonomists. A pictogram shall be selectable by a mouse click. This enables a deeper insight in the current problem, with further

key figures and diagrams (Fig. 3: dp 8), as well as a video player (Fig. 3: dp 7) to depict the simulation sequence at the current problem time. Design point 6 of Fig. 3 indicates the time interval between two critical situations. This interactive surface contains all analysis results without an overloading of the display with information. Now, users are able to regard their data from a coarse overview to a deeper insight, if needed. This is in response to the desires of the interviewed persons. The survey results show that this initial design approach has several shortcomings:

- A number of problems at the timeline (Fig. 3: dp 1) cannot be displayed at its best; i.e., a bar could overlap other bars, if they occurred nearly at the same time.
- The permanent assignment of the colors to the appropriate evaluation methods was described as inconvenient, by the survey participants.
- It is hard to compare the results over the time for the respective method.
- There isn't a possibility to choose a specific range, e.g., from second 5 to 20.
- The duration of a single problem is not that simple to recognize from the timeline.

We solved these problems in the final design, shown in Fig. 4 (dp 1), by using a single row for every method on the timeline. The color of a horizontal bar doesn't show the method anymore, but the severity of the problem (the darker the color, the worse the ergonomic issue). Hence, problems can't overlap anymore. Furthermore, it is possible to analyze all problems, indicated by a specific method, in a row. We have added a range slider beneath the timeline (see Fig. 3: dp 2), where users can choose a scope exact to the second. These proposals were approved by all participants involved. In response to the constraints on space, not all critical situations, within a chosen range, can be displayed at a glance (respectively as pictograms), when they consist of more than 5 problems. Due to this restriction, we have added a "previous" and a "next" button (see Fig. 4: dp 6), with the quantity of the future problems, to our final concept. If a small section on the timeline contains many short trouble spots, it becomes quickly unmanageable. The respondents want a chance to choose and to enlarge this area. In the new approach, they can achieve this by specifying the considered area with the slider. This part is expanded horizontally. All problems, which are in front of and behind the range of interest are compressed and grayed out. The critical ergonomic issues of the chosen range are displayed in more detail, as previously mentioned. There is a scrollbar beneath the timelime to change the current view of the problems within the selected area; i.e., the pictograms and the corresponding single result values. The single scores of the evaluation methods are displayed in boxes above the timeline (Fig. 4: dp 3). In contrast to the first concept, we order the evaluation scores by the analysis methods (Fig. 4: dp 3). This enables a comparison of several problems over time and for one method. The adverse work postures are presented in form of pictograms (Fig. 4: dp 5) with additional indications, like the weight of an object (carried along by the worker), as mentioned above. The experts expressed the desire that the

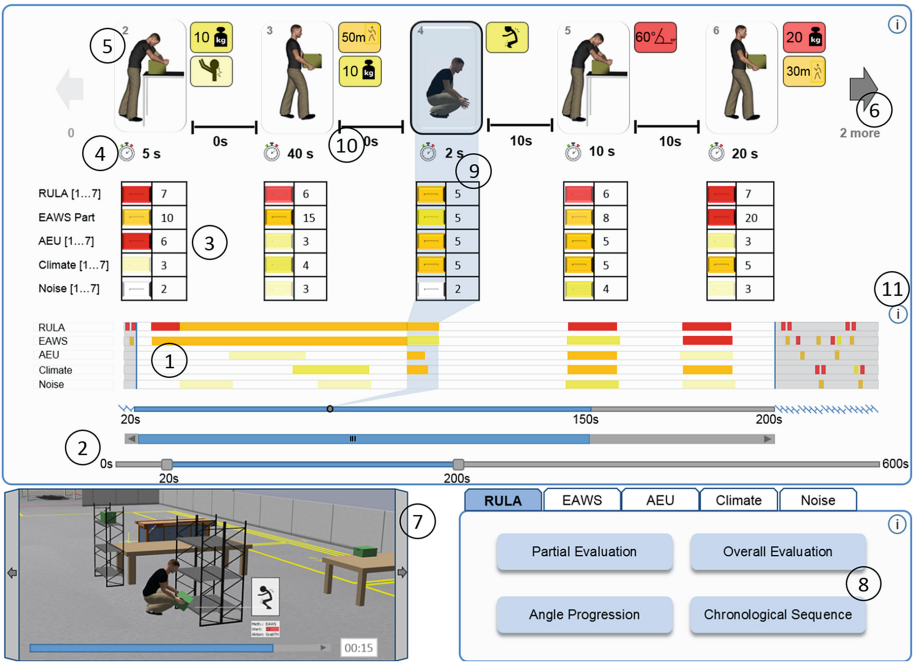

Fig. 4. Final concept. (1) Timeline (2) Sliders (3) Evaluation-scores (4) Duration of one critical issue (5) Pictogram with additional stress hints (6) Next-button shows further ergonomic problems (7) Video sequence player (8) Further information about critical situations (9) Highlighting of current selected problem (10) Distance time between critical situations (11) Mouse-over tooltip at the "i"-symbol

correlation between the timeline and a corresponding problem (the single scores and the pictogram) needs to be highlighted. We realize this wish as shown in Fig. 4 (dp 9). If the pictogram is selected, a colored background stripe appears. According to the interviews, we have swapped the lower parts of Fig. 3 (dp 1 - dp 6) with the upper parts. Now, the sections "video player" (Fig. 3: dp 7) and "detail view" (Fig. 3: dp 8) are located on the bottom. The participants consider the latter merely as additional information. The main focus lies on the overview; i.e., the timeline and the single scores including the pictograms. Therefore, we have rearranged the design and the main parts are on top. At the wish of the participants, the detail view in the first concept (Fig. 3: dp 8) is refined (Fig. 4: dp 8). The information, which is included there, may be very complex and composed of different parts, such as lists, plots, or other descriptions. These data are necessary for a more precise investigation and are requested on demand. Hence, subcategories were introduced in the new concept, in order to avoid an overloading of the graphical user interface with information which are not required in each case. In addition, the results of all analysis methods for the current issue are provided over several tabs. Therefore, an ergonomist can examine possible

relations between the outcomes of several analysis methods. The duration of one critical issue (Fig. 4: dp 4) is even more important than the time interval between the problems (Fig. 4: dp 10), especially if the worker carries a heavy weight over longer distance. Hence, we have appended this time designation at the request of the ergonomists. As a result of the survey we changed the "stickman"-pictograms (Fig. 5, left) to the "digital human model"-pictograms (Fig. 5, right). Although, it is to be noted that the participants were discordant in this issue. Nevertheless, the majority approved the modification, due to the more realistic representation. The usage of this alternative allows a good assessment of the body posture, especially of 3D movements, such as trunk rotations.

Fig. 5. Pictogram in the style of a stickman (left) and more realistic as digital human model (right)

In order to simplify the usage, some interviewees have proposed to provide mouse-over info boxes direct at the interactive parts. We deviated from this proposal, since permanently opening boxes during navigation might be cumbersome for the users. Nevertheless, we have realized this idea by adding tooltips at the right-hand edge of the display (Fig. 4: dp 11), which are accepted generally.

7 Conclusions

In this paper, we have discussed two concepts to visualize ergonomic analysis data and to explore it. The first concept (Fig. 3) was prepared on basis of several expert interviews. We have realized the requirements of the experts, such as an intuitive handling, a first overview of all critical situations, as well as the providing of deeper information on demand. An evaluation of this prototype with experts from the field of ergonomics, visualization, and usability led to significant changes in our initial concept (Fig. 3). This demonstrates the importance of our user studies. The disadvantages of the first concept were highlighted and eliminated in several iterative loops. Furthermore, we explained why we use pictograms (see Fig. 5) and why we changed the order of certain graphical elements in the final concept, as a result of the survey.

References

1. Mühlstedt, J.: Entwicklung eines Modells dynamisch-muskulärer Arbeitsbeanspruchungen auf Basis digitaler Menschmodelle. Universitätsverlag Chemnitz, Chemnitz (2012)

2. Wischniewski, S.: Delphi survey: digital ergonomics 2025 - trends and strategies for increasing product usability and designing safe, healthy and competitive socio-technical work systems (2013). http://mreed.umtri.umich.edu/DHM2013Proceedings/
3. British Standards Institute Staff. Safety of Machinery. Ergonomic Design Principles. Terminology and General Principles, B S I Standards (2006)
4. DGVU. Rolle und Aufgabe der Fachkraft für Arbeitssicherheit. http://www.dguv.de/sifa-online/Fachkraft-f%C3%BCr-Arbeitssicherheit/Rolle-und-Aufgabe/index.jsp. (20 February 2015)
5. Schlick, C.M., Bruder, R., Luczak, H.: Arbeitswissenschaft. Springer, Berlin (2010)
6. Heft, W., Spitzhirn, M., Rosenthal, P.: A survey on visualization in industrial ergonomics. In: Rosenthal, P., Laramee, R.S., Kirby, M., Kindlmann, G.L. (eds.) Proceedings of the EuroVis Workshop on Reproducibility. Verification, and Validation in Visualization, pp. 7–8. Eurographics Association, Germany (2013)
7. McAtamney, L., Corlett, E.N.: Rula: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
8. FIOH. Rula (rapid upper limb assessment). http://www.ttl.fi/en/ergonomics/methods/. 20 February 2015
9. Kugler, M., Bierwirth, M., Schaub, K., Sinn-Behrendt, A., Feith, A., Ghezel-Ahmadi, K., Bruder, R.: Förderschwerpunkt 2007: KoBRA - Kooperationsprogramm zu normativem Management von Belastungen und Risiken bei körperlicher Arbeit: Ergonomie in der Industrie - aber wie?; Handlungshilfe für den schrittweisen Aufbau eines einfachen Ergonomiemanagements. Bundesanst. für Arbeitschutz und Arbeitsmedizin, Berlin (2010)
10. Magnenat-Thalmann, N., Thalmann, D.: Handbook of Virtual Humans. Wiley, Chichester (2004)
11. Spanner-Ulmer, B., Mühlstedt, J.: Digitale Menschmodelle als Werkzeuge virtueller Ergonomie: Ergebnisse einer empirischen Studie. Industrie-Management: Zeitschrift für industrielle Geschäftsprozesse **26**(8), 69–72 (2010)
12. Siemens. Jack. http://blog.industrysoftware.automation.siemens.com/blog/2009/03/19/are-digital-humans-cool/. (20 February 2015)
13. Gantt, H.L.: Work, Wages, and Profits. Industrial management library. Engineering Magazine Company, New York (1913)
14. Aigner, W., Miksch, S., Schuman, H., Tominski, C.: Visualization of Time-Oriented Data. Human-Computer Interaction, 1st edn. Springer, London (2011)
15. Rosenthal, P., Pfeiffer, L., Müller, N.H., Ohler, P.: Visruption: intuitive and efficient visualization of temporal airline disruption data. Comput. Graph. Forum **32**(3), 81–90 (2013)
16. Zhao, J., Chevalier, F., Balakrishnan, R.: Kronominer: using multi-foci navigation for the visual exploration of time-series data. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 2011, pp. 1737–1746. ACM, New York (2011)
17. Plaisant, C., Milash, B., Rose, A., Widoff, S., Shneiderman, B.: Lifelines: visualizing personal histories. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI 1996, pp. 221–227. ACM, New York (1996)
18. Wongsuphasawat, K., Gómez, J.A.G, Plaisant, C., Wang, T.D., Taieb-Maimon, M., Shneiderman, B.: Lifeflow: visualizing an overview of event sequences (video preview). In: Tan, S., Amershi, S., Begole, B., Kellogg, W.A., Tungare, M. (eds.) CHI Extended Abstracts, pp. 507–510. ACM (2011)

19. Legg, P.A., Chung, D.H.S., Parry, M.L., Jones, M.W., Long, R., Griffiths, I.W., Chen, M.: Matchpad: interactive glyph-based visualization for real-time sports performance analysis. Comp. Graph. Forum **31**(3pt4), 1255–1264 (2012)
20. Jänicke, H., Borgo, R., Mason, J.S.D., Chen, M.: Soundriver: semantically-rich sound illustration. Comput. Graph. Forum **29**(2), 357–366 (2010)
21. Shneiderman, B.: The eyes have it: a task by data type taxonomy for information visualizations. In: Proceedings of the 1996 IEEE Symposium on Visual Languages, VL 1996, pp. 336–343. IEEE Computer Society, Washington (1996)